Complete Summary

GUIDELINE TITLE

Single-breath carbon monoxide diffusing capacity, 1999 update.

BIBLIOGRAPHIC SOURCE(S)

American Association for Respiratory Care (AARC). Single-breath carbon monoxide diffusing capacity, 1999 update. Respir Care 1999 Jan;44(1):91-8. [35 references]

COMPLETE SUMMARY CONTENT

SCOPE

DISEASE/CONDITION(S)

Pulmonary disease

GUIDELINE CATEGORY

Diagnosis
Evaluation

CLINICAL SPECIALTY

Pulmonary Medicine

INTENDED USERS

Respiratory Care Practitioners

GUIDELINE OBJECTIVE(S)

- To improve the consistency and appropriateness of respiratory care and serve as a guide for education and research.
- To update clinical practice guidelines on single-breath carbon monoxide diffusing capacity

TARGET POPULATION

- Individuals with parenchymal lung diseases including: idiopathic pulmonary fibrosis (IPF, also known as usual interstitial pneumonitis, or UIP) and bronchiolitis obliterans organizing pneumonia (BOOP, or cryptogenic organizing pneumonia, COP), diseases associated with dusts such as asbestos, or drug reactions (eg, from amiodarone) or related to sarcoidosis
- Individuals with emphysema, cystic fibrosis, chronic bronchitis, and asthma
- Individuals with cardiovascular diseases (eg, primary pulmonary hypertension, acute or recurrent thromboembolism, or pulmonary edema)
- Individuals with systemic diseases (eg, rheumatoid arthritis, systemic lupus erythematosus) with pulmonary involvement
- Individuals receiving chemotherapy agents or other drugs (eg, amiodarone, bleomycin) known to induce pulmonary dysfunction
- Individuals with pulmonary hemorrhage
- Individuals with pulmonary infections (eg, pneumocystis pneumonia)

INTERVENTIONS AND PRACTICES CONSIDERED

Single-breath diffusing capacity for carbon monoxide (DLCOsb), sometimes referred to as the transfer factor for carbon monoxide (TCO)

MAJOR OUTCOMES CONSIDERED

Measurement of single-breath diffusion capacity for carbon monoxide (DLCOsb):

- DLCO is usually expressed in mL CO min-1 x torr-1 at standard temperature and pressure dry (STPD).
- The alveolar volume (VA) at which the DLCOsb is measured is also commonly reported; the units for the VA are liters at body temperature and pressure, saturated with water vapor (BTPS).
- The ratio of DLCO to VA is also commonly reported as the DL/VA or simply D/VA.

METHODOLOGY

METHODS USED TO COLLECT/SELECT EVIDENCE

Searches of Electronic Databases

DESCRIPTION OF METHODS USED TO COLLECT/SELECT THE EVIDENCE

Not stated

NUMBER OF SOURCE DOCUMENTS

Not stated

METHODS USED TO ASSESS THE QUALITY AND STRENGTH OF THE EVIDENCE

Not stated

RATING SCHEME FOR THE STRENGTH OF THE EVIDENCE

Not applicable

METHODS USED TO ANALYZE THE EVIDENCE

Systematic Review

DESCRIPTION OF THE METHODS USED TO ANALYZE THE EVIDENCE

Not stated

METHODS USED TO FORMULATE THE RECOMMENDATIONS

Not stated

RATING SCHEME FOR THE STRENGTH OF THE RECOMMENDATIONS

Not applicable

COST ANALYSIS

A formal cost analysis was not performed and published cost analyses were not reviewed.

METHOD OF GUIDELINE VALIDATION

External Peer Review

DESCRIPTION OF METHOD OF GUIDELINE VALIDATION

Consultants to the Working Group may review the initial draft of the guideline. After completion by the Working group, the draft is reviewed by the entire Steering Committee and then by a Review Panel, persons engaged in all facets of the delivery of respiratory care who have volunteered to review drafts of the Guidelines before publication.

RECOMMENDATIONS

MAJOR RECOMMENDATIONS

Description/Definition

Diffusing capacity is a measurement of carbon monoxide (CO) transfer from inspired gas to pulmonary capillary blood. During the test, the subject inspires a gas containing CO and one or more tracer gases to allow determination of the gas exchanging capability of the lungs. Although several different methods of measuring DLCO have been described, the most commonly used technique is the single-breath maneuver, or DLCOsb. For purposes of this guideline, recommendations associated with the DLCOsb are referenced. Many of these standards apply indirectly to other methods of measuring diffusing capacity.

- DLCO is usually expressed in mL CO min-1 x torr-1 at standard temperature and pressure dry (STPD).
- The alveolar volume (VA) at which the DLCOsb is measured is also commonly reported; the units for the VA are liters at body temperature and pressure, saturated with water vapor (BTPS).
- The ratio of DLCO to VA is also commonly reported as the DL/VA or simply D/VA.

Settings:

- Pulmonary function laboratories
- Cardiopulmonary laboratories
- Clinics
- Physicians' offices

Indications:

Tests of diffusing capacity may be indicated for (Specific conditions and direction of change in DLCO are shown in the Appendix in the guideline document):

- evaluation and follow-up of parenchymal lung diseases including: idiopathic pulmonary fibrosis (IPF, also known as usual interstitial pneumonitis, or UIP) and bronchiolitis obliterans organizing pneumonia (BOOP, or cryptogenic organizing pneumonia, COP), diseases associated with dusts such as asbestos, or drug reactions (eg,from amiodarone) or related to sarcoidosis; and for quantification of disability associated with interstitial lung disease;
- evaluation and follow-up of emphysema and cystic fibrosis; and differentiating among chronic bronchitis, emphysema, and asthma in patients with obstructive patterns; and for quantification of impairment and disability.
- evaluation of cardiovascular diseases (eg, primary pulmonary hypertension, acute or recurrent thromboembolism, or pulmonary edema);
- evaluation of pulmonary involvement in systemic diseases (eg, rheumatoid arthritis, systemic lupus erythematosus);
- evaluation of the effects of chemotherapy agents or other drugs (eg, amiodarone, bleomycin) known to induce pulmonary dysfunction;
- evaluation of pulmonary hemorrhage;
- as an early indication of certain pulmonary infections (eg, pneumocystis pneumonia);
- prediction of arterial desaturation during exercise in some patients with lung disease.

Limitations of Methodology/Validation of Results:

- Limitations of the common methods used for DLCO include:
    1. DLCO should be corrected for hemoglobin (Hb) level according to the method described by Cotes and co-workers.
        - For adolescent boys(>= 15 years of age) and adult men, the Hb is adjusted to a value of 14.6 g/dL: Hb-adjusted DLCO = observed DLCO (10.22 + Hb)/1.7 Hb.
        - For children < 15 years of age and women the Hb is adjusted to a value of 13.4 g/dL: Hb-adjusted DLCO = observed DLCO (9.38 + Hb)/1.7 Hb.
    2. For purposes of interpretation, DLCO should be corrected for the effects of COHb present in the subject's blood. COHb-adjusted DLCO = measured DLCO (1+ [%COHb/100]).
    3. DLCO increases with increasing altitude and appropriate correction for the alveolar or inspired oxygen pressures are recommended. Altitude-adjusted DLCO = measured DLCO (1.0 + 0.0035(PAO2 - 120]) or Altitude-adjusted DLCO = measured DLCO (1.0 + 0.0031(PIO2 - 150]) (where estimated PIO2 = 0.21 [PB - 47 torr].)
    4. A 4-minute minimum interval should elapse between subsequent maneuvers to allow test gas to be eliminated from the lungs.
    5. DLCO varies with body position; the upright seated position is recommended.
    6. Abnormal breathholding maneuvers (Valsalva or Müller) alter DLCO.
    7. Other factors that may alter measurement of DLCO include recent alcohol consumption, vigorous exercise, smoking, diurnal variation, and bronchodilators.
    8. Pregnancy (first trimester only) has been reported to be associated with an increase in DLCO. Menstruation may also influence DLCO.
    9. Breathhold time should be calculated using the method of Jones-Meade. Other methods may produce significantly different results.
- Large interlaboratory differences in measured DLCO and in percent-of-predicted DLCO have been observed and are attributed to variations in testing techniques and computational algorithms and errors in gas analysis. The choice of equipment may also influence the measured DLCO.
- Choice of reference equations may affect the final interpretation of measured DLCO values.
- Validation of the testing technique and equipment may include but is not limited to
    1. Volume accuracy of spirometer should be < ± 3% over an 8-L volume (ie, meets or exceeds all ATS recommendations) and must be checked each day that the test is performed, using a 3.00 L (minimum) syringe. Spirometer must maintain accuracy with varying gas concentrations.
    2. Gas analyzers should be subjected to a 2-point calibration before each test. Manufacturers should be encouraged to provide software and techniques by which analyzer linearity may be easily checked (eg, dilution technique). Gas analyzer linearity should be
        - within ± 1%, from zero to full span, of maximal value over the duration of the test,
        - formally checked at least quarterly.
    3. Timing device should be checked every 3 months and be accurate within ± 1% over a 10-second period.

4. The entire circuit resistance should be < 1.5 cm H2O/L/s at a flow of 6 L/s. The addition of in-line filters may cause the circuit resistance to exceed recommendations.
5. The apparatus dead space should be < 0.1 L. In-line filters need to be accounted for when determining entire system dead space as well as discard volume (before alveolar collection).
6. Demand valve sensitivity of < 10 cm H2O is required for 6 L/s flow through a valve and circuit (if a compressed gas source is used).
7. Chemical absorbers (for CO2 and H2O) or selectively permeably tubing should be replaced at the frequency recommended by the manufacturer, when saturated (as indicated by color change) or sooner. In addition, the chemical absorbers should be placed in the proper order (ie, CO2 absorber should precede H2O absorber), should be replaced when exhausted, and should be arranged according to how alveolar gas is analyzed.
8. Normal standard subjects (biologic controls) may be used to establish intrasubject coefficient of variation and to serve as a quality control population.

Assessment of Test Quality:
Individual test maneuvers and results should be evaluated according to the ATS recommendations.

- Use of proper quality-controlled equipment.
- Provision of test instructions before testing commences and determination that the subject is able to follow commands.
- Inspiratory volume exceeding 90% of the largest previously measured vital capacity (FVC or VC), attained in < 2.5 s in healthy subjects and within 4 s in patients with moderate to severe airway obstruction.
- Breathhold times of 9-11 seconds, with no evidence of leaks or Valsalva or Müller maneuvers.
- After the breathhold, there should be appropriate clearance of dead space (anatomic plus system) and proper collection and analysis of alveolar gas.
    1. The washout volume (ie, dead space) should be 0.75-1.00 L or 0.50 L if the subject's VC is less than 2.0 L. If a washout volume other than 0.75-1.00 L must be used, it should be noted.
    2. If an in-line filter is used, when determining discard volume, the filter dead space must be accounted for.
    3. For alveolar-gas sample-bag systems, the volume of the alveolar gas sample should be 0.5-1.0 L obtained in < 4 seconds.
- Two or more acceptable tests should be averaged; the DLCO values should be reproducible to within 10% or 3 mL CO x min -1 x torr -1, whichever is greater. We recommend empirically that no more than 4-6 maneuvers be performed.
- The subject should have refrained from smoking for 24 hours prior to the test; however, because subjects do not always comply, the time of the last smoking event should be recorded.
- Corrections for Hb, COHb should be included as noted above; correction for tests performed at altitude is recommended. If Hb correction is made, both the corrected and uncorrected DLCO values should be reported.

Resources

- Equipment:
    1. Volume-measuring device must meet or exceed ATS recommendations.
    2. Appropriate gas analyzers dependent on the methodology employed; certified calibration gases for use before each series of measurements.
    3. CO oximeter for analysis of total Hb and COHb is strongly recommended.
- Personnel: Diffusing capacity tests should be performed under the direction of a physician trained in pulmonary function testing. The value of diffusing capacity results can be compromised by poor patient instruction secondary to inadequate technologist training. Thus, technologists should have documented training, with continued competency assessments in diffusing capacity administration and recognition of errors encountered in the testing process as well as a sound understanding of pulmonary pathophysiology. Diffusing capacity testing may be performed by persons who meet criteria for either Level I or Level II.
    1. Level I: The technologist performing DLCO should be a high school graduate or equivalent with a demonstrated ability to perform basic pulmonary function studies such as spirometry (and DLCOsb). Level I personnel should perform DLCO tests only under the supervision of a Level II individual or a physician.
    2. Level II: Personnel supervising DLCO testing should have formal education and training (as a part of a program in respiratory therapy or pulmonary function technology or 2 years of college in biological sciences and mathematics) and 2 or more years performing spirometry, lung volumes, and diffusing capacity tests. One or more of the following credentials is recommended: RPFT, CPFT, RRT, CRT.

Monitoring:
(Also see Assessment of Test Quality section) The following should be evaluated during the performance of the DLCO measurement to assess the validity of the results:

- Acceptability of the maneuvers and reproducibility of DLCOsb:
    1. patient positioning: subjects should be seated for at least 5 minutes prior to testing and should remain seated throughout the DLCO testing session,
    2. interval between tests: at least 4 minutes between sequential tests to allow elimination of tracer gas,
    3. reproducibility, with at least 2 acceptable tests that are within ± 10% or 3 mL CO(STPD)/min/mm Hg of the average DLCO.
- Level of understanding (of test instructions), effort and cooperation by the subject.
- Equipment function or malfunction (eg, calibration), with equipment quality control performed as recommended, any time accuracy is suspect or if the equipment is moved to a different location.
    1. Volume calibration and leak testing performed on a daily basis,
    2. Gas analyzer linearity checked quarterly,
    3. Timer tested quarterly
    4. Tests on standard subjects (biologic controls, or bio-QC) should be performed at least on a quarterly basis and any time accuracy is suspect.

        - Standard subjects should be tested more frequently initially to establish statistical variation for comparison.
        - It is advantageous to perform Bio-QC at weekly or semi-monthly intervals.
- Reference equations: each laboratory should select reference equations appropriate for the methods and the population tested.
- Inspired oxygen concentration: test gas concentration should be 20.93% and at sea level pressure. Subjects should remain off supplemental oxygen for at least 5 minutes prior to performing the first test. Technologists should document (in the final report)a patient's inability to remain off supplemental oxygen for the allotted time.
- The final report should contain a statement about test quality.
- The final report should contain the DLCO, the corrected DLCO (Hb, COHb, altitude), and the Hb value used for correction. The alveolar volume (VA) and DL/VA (ie, the ratio of diffusing capacity to the lung volume at which the measurement was made) may be included in the report. These values are helpful for purposes of interpretation. The final report should indicate which method was used to correct the raw DLCO value and for what the DLCO value is being corrected [eg, corr DLCO (Hb), corr DLCO (CO)].
- DLCOsb results should be subject to ongoing review by a supervisor, with feedback to the technologist. Quality assurance (QA) and/or quality improvement (QI) programs should be designed to monitor the technologist both initially and on an ongoing basis.

Frequency:
The frequency at which DLCO measurements should be repeated depends on the clinical question(s) to be answered.

Infection Control:
Diffusing capacity tests are relatively safe procedures, but the possibility of cross-contamination exists, either from the patient-patient or patient-technologist interface.

- Technologists should exercise Standard Precautions for all patients, follow recommendations of the Centers for Disease Control and Prevention for control of exposure to tuberculosis and droplet nuclei, and, in addition, institute appropriate precautions empirically for airborne, droplet, and contact agents pending confirmation of diagnosis in patients suspected of having serious infections.
- Proper use of barrier devices (eg, protective gloves) may be useful to prevent spread of contagion via direct contact. Hand washing must always be performed between patients, and protective gloves must be worn if there are open cuts, or sores, on the technologist's hands.
- Due to the nature of the DLCO maneuvers and the likelihood of coughing when the test is performed by subjects with known or suspected active infection with Mycobacterium tuberculosis or other airborne organisms, recommended precautions are:
    1. The room in which the DLCO test is performed should meet or exceed the recommendations of U.S. Public Health Service for air changes and ventilation. The ideal situation is to establish an area in the testing department specially ventilated for isolation patients. We strongly recommend that, if this is not possible, the patient be returned to the

isolation room as soon as possible, and the testing room be closed for a minimum of 1 to 2 hours.
    2. Pulmonary function technologists performing procedures on patients with potentially infectious airborne diseases should wear a personal respirator that meets OSHA recommendations, especially if the testing itself induces coughing.
- The mouthpiece, tubing, and any parts of the system that come into contact with the subject should be disposable or sterilized between patients. If sterilization is not feasible, then high-level disinfection should be performed. It is unnecessary to routinely clean the interior surface of the spirometer.
    1. Visible condensation, from expirate, warrants cleaning of the system before testing another patient.
    2. Bacterial filters that allow rebreathing may be used in circuit, although their efficacy is not well documented. However, such filters may impose added resistance during inspiration or expiration and affect the timing of the DLCO maneuver. If a filter is used, the filter dead-space volume should be considered in the calculation of DLCO and VA.

CLINICAL ALGORITHM(S)

None provided

EVIDENCE SUPPORTING THE RECOMMENDATIONS

TYPE OF EVIDENCE SUPPORTING THE RECOMMENDATIONS

Not specifically stated for each recommendation: The guideline is developed from a thorough review of the literature, surveys of current practice, and the expertise of the members of the working group.

BENEFITS/HARMS OF IMPLEMENTING THE GUIDELINE RECOMMENDATIONS

POTENTIAL BENEFITS

Appropriate utilization of single-breath carbon monoxide diffusing capacity tests

POTENTIAL HARMS

- DLCOsb requires breathholding at total lung capacity (TLC); some patients may perform either a Valsalva (higher than normal intrathoracic pressure) or Müller (lower than normal intrathoracic pressure) maneuver. Either of these can result in alteration of venous return to the heart and pulmonary capillary blood volume.
- Interruption of supplemental oxygen may result in oxyhemoglobin desaturation.
- Transmission of infection is possible via improperly cleaned mouthpieces or as a consequence of the inadvertent spread of droplet nuclei or body fluids (patient-to-patient or patient-to-technologist).

CONTRAINDICATIONS

CONTRAINDICATIONS

Absolute contraindications to performing a diffusing capacity test are:

- the presence of carbon monoxide toxicity
- dangerous levels of oxyhemoglobin desaturation without supplemental oxygen.

Relative contraindications to performing a diffusing capacity test are

- mental confusion or muscular incoordination preventing the subject from adequately performing the maneuver or inability to obtain or maintain an adequate lip seal on the instrument mouthpiece;
- a large meal or vigorous exercise immediately before the test;
- smoking within 24 hours of test administration (smoking may have a direct effect on DLCO independent of the effect of COHb);
- decreased lung volumes that would not yield valid test results;
- devices that are improperly calibrated or maintained or the unavailability of a qualified operator.

IMPLEMENTATION OF THE GUIDELINE

DESCRIPTION OF IMPLEMENTATION STRATEGY

An implementation strategy was not provided.

INSTITUTE OF MEDICINE (IOM) NATIONAL HEALTHCARE QUALITY REPORT CATEGORIES

IOM CARE NEED

Getting Better
Living with Illness
Staying Healthy

IOM DOMAIN

Effectiveness
Safety

IDENTIFYING INFORMATION AND AVAILABILITY

BIBLIOGRAPHIC SOURCE(S)

American Association for Respiratory Care (AARC). Single-breath carbon monoxide diffusing capacity, 1999 update. Respir Care 1999 Jan;44(1):91-8. [35 references]

ADAPTATION

Not applicable: The guideline was not adapted from another source.

DATE RELEASED

1999 Jan

GUIDELINE DEVELOPER(S)

American Association for Respiratory Care - Professional Association

SOURCE(S) OF FUNDING

American Association for Respiratory Care (AARC)

GUIDELINE COMMITTEE

Diffusion Capacity Working Group

COMPOSITION OF GROUP THAT AUTHORED THE GUIDELINE

Names of Working Group Members: Carl Mottram, RRT, RPFT, Chairman; Susan Blonshine, BS, RRT, RPFT; Robert A. Brown, BS, RRT, RPFT; Gregg L. Ruppel, MEd, RRT, RPFT; Jack Wanger, MBA, RRT, RPFT.

FINANCIAL DISCLOSURES/CONFLICTS OF INTEREST

Not stated

GUIDELINE STATUS

This is the current release of the guideline. This guideline updates a previously issued version (Respir Care 1993 May;38(5):511-5).

According to the guideline developer, this version has been reviewed within the last five years and is considered current.

An update is not in progress at this time.

GUIDELINE AVAILABILITY

Electronic copies: Available from the American Association for Respiratory Care (AARC) Web site.

Print copies: Available from AARC, CPG Desk, 11030 Ables Ln, Dallas, TX 75229-4593.

AVAILABILITY OF COMPANION DOCUMENTS

The following is available:

- The AARC Clinical Practice Guidelines. Respir Care 1996;41(7):647-53.

Print copies: Available from the American Association for Respiratory Care (AARC), CPG Desk, 11030 Ables Ln, Dallas, TX 75229-4593; Web site: www.aarc.org.

PATIENT RESOURCES

None available

NGC STATUS

This summary was completed by ECRI on April 25, 1999. The information was verified by the guideline developer on April 25, 1999.

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Date Modified: 11/15/2004